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ADVANCES IN SEWAGE TREATMENT AND PRESENT STATUS OF THE ART

PROGRESS REPORT OF THE COMMITTEE OF THE SANITARY ENGINEERING DIVISION ON SEWERAGE AND SEWAGE TREATMENT

Headquarters of the Society
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GUIDEPOST FOR TECHNICAL READERS

"Proceedings-Separates" of value or significance to readers in various fields are here listed, for convenience, in terms of the Society's Technical Divisions. Where there seems to be an overlapping of interest between Divisions, the same Separate number may appear under more than one item. For a description of papers open to discussion refer to the current issue of *Civil Engineering.*

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AMERICAN SOCIETY OF CIVIL ENGINEERS

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REPORTS

ADVANCES IN SEWAGE TREATMENT AND PRESENT STATUS OF THE ART

PROGRESS REPORT OF THE COMMITTEE OF THE SANITARY ENGINEERING DIVISION ON SEWERAGE AND SEWAGE TREATMENT

This report of the Committee on Sewerage and Sewage Treatment covers the period from January 1, 1950, to October 1, 1951—a period of post-war inflation. As yet, no pronounced readjustment of prices has occurred. Because of the impact of the Korean fighting and the inauguration of a national program of defense preparation, shortages of steel, cement, copper, and other materials have begun to appear. In 1951, various controls were imposed.

Legislative Development

Under *Public Law No. 845*, activities in sewage research and public health are being continued.

Sewage Research.—The annual review of the literature on sewage and waste treatment and stream pollution by the Committee on Research of the Federation of Sewage and Industrial Wastes Associations (1)[1] (2) continues to summarize the art each year from the research, laboratory, and operating standpoints, as it has done each year since 1933.

In the summary of the literature of 1950 (2), the number of references increased to 661, in part because of the growing interest in the handling of industrial wastes. The literature reveals neither marked changes nor improved or new sewage treatment processes, but it does indicate a steady progress in modifications and a gradual firm establishment of principles. Understanding of the theory and mechanism of various processes that have been utilized successfully for many years is beginning to catch up with practice.

In view of the exhaustive nature of the annual review, published by the Federation of Sewage and Industrial Wastes Associations (2), from the standpoint of literature, this report is directed chiefly toward the engineering phases of the art and toward topics that are authenticated but not always published.

Note.—Please forward all comments on this report directly to Chairman Langdon Pearse, 910 So. Michigan Ave., Chicago 5, Ill. Progress reports are published in *Proceedings-Separates* only.

[1] Numerals in parentheses, thus: (1), refer to corresponding items in the Bibliography (see Appendix).

The appropriations to various states and institutions under *Public Law No. 845* concerning research total $955,761 for 1950–1951.

United States Public Health Service.—In a country-wide survey (3), the United States Public Health Service (USPHS) now finds a need for a sanitation program estimated to cost between $9,000,000,000 and $12,000,000,000. Under *Public Law No. 845*, the USPHS has entered upon its water pollution control activities and is preparing reports on the various main drainage basin areas in the United States. The first of the series has appeared on the subject of the Tennessee River Drainage Basin (4), and the second on the Missouri River Drainage Basin (5).

Water Pollution Control

In October, 1950, the USPHS issued a bulletin (6) outlining a suggested water pollution control act, in an effort to establish uniformity among the laws governing water pollution control in the various states. The bulletin entitled, "Water Pollution in the United States" (3) lists fifty-three official state and interstate water pollution control agencies as defined under *Public Law No. 845*, and, in addition, eleven interstate commissions.

The development of compacts and other interstate agreements was summarized in the report (7) entitled, "Advances in Sewage Treatment in the Decade Ending with the Year 1949." Recently, several additional reports have been published.

Ohio River Valley Water Sanitation Commission.—In its second annual report (8), this commission indicates that, in cities having a population of five thousand and over, nine treatment plants already have been built in a district that includes 155,000 sq miles and a population of 17,600,000. Four works are under construction. The detailed plans are approved for 48 cities and those for 134 more cities are in the planning stage.

The commission has established a water-quality objective in the Cincinnati (Ohio) pool, a 22-mile reach in the Ohio River (9). Construction has begun on sewage treatment works at Cincinnati and at Madison, Evansville, and Clarksville, in Indiana. Plans are being prepared in Illinois, Indiana, Ohio, Kentucky, Pennsylvania, Virginia, and West Virginia. The commission has issued (10) a bulletin on the control of plating-room wastes, prepared by a co-operating committee of representatives from various industries.

The water-quality conditions and changes revealed by a simultaneous sampling of the 963-mile stretch from Pittsburgh, Pa., to Cairo, Ill., are outlined (11). A guide for the evaluation of the sanitary condition of waters used for potable supplies and recreational uses has been adopted (12), stating the bacterial quality objectives for the Ohio River. This guide is largely the work of H. W. Streeter, M. ASCE. The most recent bulletin (13) concerns brine contamination in the Muskingum River.

Interstate Commission on the Potomac River Basin.—The Interstate Commission on the Potomac River Basin has been concerned with three principal types of wastes, namely—sanitary sewage, industrial wastes, and silt. An advisory committee on industrial wastes was created in 1946, which presented an industrial waste symposium in 1950 (14).

Pollution Surveys.—Various states and agencies thereof and the International Joint Commission have presented reports on pollution of waters.

Alabama.—In Alabama, the Alabama Water Improvement Advisory Commission has studied the pollution in the streams (15).

Florida.—E. B. Phelps and D. E. Barry, J. M. ASCE (16), have reported on stream sanitation in Florida, covering the water quality and its impairment, stream flow analysis, and pollutional data on thirty-two major watersheds including wastes from the citrus, pulp, and paper industries. Five cities discharge sewage to underground water. In certain areas, pollution was found to be in need of prompt correction. However, these areas constitute but a small proportion of the total water surfaces of the state.

Illinois River (Illinois).—In accordance with *House Bill No. 603* (approved on July 12, 1949, by the 66th General Assembly of the State of Illinois), the Illinois River Pollution Commission reported (17) to the governor and members of the 67th General Assembly of the State of Illinois on January 30, 1951, on the state of pollution in the Illinois River. The report indicates that downstream from The Sanitary District of Chicago, the river has a sewer-connected population of over 300,000 persons, and the industrial wastes, if discharged into the river untreated, would amount to an equivalent population of 4,000,000. The river is subject to three general types of pollution: Silt originating from soil erosion, domestic sewage, and industrial wastes. Sewage treatment works and industrial recovery processes remove about 87.2% of the latter. The report (17) contains the following:

> "Fortunately, no public water supplies have been affected, because, except for Grafton (1940 census 1,110), most communities use ground water supplies. The silt in the river water damages it for industrial purposes, and has affected navigation and electric power facilities. The most noticeable effects of pollution are the damages to aquatic recreational features. At no point is the river considered safe for swimming. Except in the extreme lower reaches, it has no value for game fishing."

Sewage treatment of some type is available to 4,686,200 persons of the 5,201,300 residents of the Illinois River Basin communities. An additional 87,337 persons in 23 communities have sewers with primary treatment facilities. The remaining 144,459 residents of 29 communities have sewers, but no treatment facilities.

The industrial waste load now discharged into the Illinois River is estimated at an equivalent of 1,900,000 persons. Further pollution abatement in this field will depend on the study of the special problems of industrial waste disposal.

The commission believed that it lacked " *** jurisdiction *** to make recommendations as to the need for more or less diversion of Lake Michigan water into the Illinois River."

Potential Conservation Areas Along the Illinois River as Part of Flood Protection.—Prior to the foregoing Illinois River pollution report (17), the Illinois Department of Conservation published its report (18) in order to demonstrate the possibility of converting certain drainage and levee districts with limited flood control value from their present marginal agricultural use into public hunting and fishing grounds.

Housatonic River, in Massachusetts.—In 1949 a study (19) was made by the Massachusetts Department of Public Health of the conditions of the Housatonic River in western Massachusetts, outlining the sources of pollution, and the treatment of sewage and industrial wastes required for maintaining the river in a suitable condition for recreational boating, for irrigation of crops not used for consumption without cooking, and for maintaining a habitat for wild life and game fish.

At the Massachusetts-Connecticut state line, the river has a drainage area of 532 sq miles, which contains (as of 1945) more than 17 towns, with a resident population of 82,000 persons. The river flow draining 280 sq miles of this area averages 1.664 cu ft per sec per sq mile, with a minimum monthly average of 81 cu ft per sec, or about 0.289 cu ft per sec per sq mile. The flow is influenced by releases from industrial mill ponds. Except in the vicinity of Pittsfield, Mass., and the communities along the Housatonic River, the drainage area is sparsely populated. The discharge of industrial wastes is a major factor in the pollution of the river, contributing about 90% of the organic load, with a volume of 7.58 mgd, mostly from paper and textile industries.

The Massachusetts Department of Public Health recommends that the sewage of 4 smaller towns receive primary treatment plus chlorination and that the Pittsfield works be enlarged to handle the domestic and industrial wastes from Dalton, Mass., in addition to that of Pittsfield. Experimental work has shown that the supply of available nitrogen and phosphorus is adequate for effective biological treatment of the mixed wastes.

Sudbury River.—Pollution conditions along the Sudbury River in Massachusetts were reported by the Sudbury Valley Commission (20), which advocated pollution control in part by zoning the land uses and by diverting sewage flow, in view of the many uses of the river.

Ohio.—A recent survey (21) of the Ohio shore of Lake Erie shows that, of twenty-five bathing beaches, seventeen have coliform bacteria counts above tolerated health limits. Further examination was conducted in 1951. Marked pollution comes from the tributaries such as Euclid Creek and Doan Creek, the Cuyahoga River, the Maumee River, and the Chagrin River. In general, the raw water pumped from Lake Erie for water supply was under the limit of 5,000 coliform bacteria per 100 ml on raw water subject to conventional filtration. Turbidity is troublesome due to the erosion of shores, the silt from the tributaries, the shallow depth of Lake Erie, and the movement of the water surface caused by the wind.

Clarion River, in Pennsylvania.—A comprehensive pollution report on the Clarion River has been prepared by the firm of Camp, Dresser, and McKee (22). The problem includes wastes from wood distillation plants, pulp and paper mills, carbon plants, tanneries, and a brewery. The waste from pulp and paper mills constituted about 93% of the total organic material discharged into the river.

Pollution Surveys in Tennessee.—The Tennessee Stream Pollution Study Commission has made a report to the governor of Tennessee, as of July 1, 1950 (23), recommending a 5-year program (including cooperation with other

states) and urges abatement of the worst sources of pollution—from 17 cities, 3 state institutions, and 1 village.

Report of the International Joint Commission, United States and Canada, on the Pollution of Boundary Waters (1950).—The 1950 report of the International Joint Commission describes (24) the investigation of the pollution entering the Niagara River, Lake St. Clair, the St. Clair River, the Detroit River, and the St. Mary's River. The report indicates that, in the area surrounding the Great Lakes (excepting Lake Michigan), there are 61 municipalties with a population of 3,557,900 persons, of which number 96% are served by sewer systems and 86% by primary treatment. The total discharge of municipal wastes is about 750 mgd, and of industrial wastes, over 2,000 mgd, including a considerable volume of harmful pollutants. This industrial waste has a Biochemical Oxygen Demand (B.O.D.) equivalent to that of wastes from a population of 4,000,000.

The commission states that the objectives for the quality control of boundary waters were developed by its technical advisers under the topics: Sanitary sewage, storm water, and wastes from water craft; chemical wastes—phenolic type; chemical wastes other than phenolic; highly toxic wastes; and deoxygenating wastes.

The estimated cost of primary treatment in these three areas under reference is $43,500,000 in the United States and $21,000,000 in Canada. The cost of treatment of the industrial wastes is $22,650,000 in the United States and $3,450,000 in Canada.

Projects

Among the large projects placed under construction during the post-war period are those at New York, N. Y., Boston, Mass. (Metropolitan and Boston Main Drainage), Los Angeles, Calif., and Philadelphia, Pa.

New York City.—Beginning in 1934, New York City has built (25) (26) thirteen sewage treatment works, now treating about 391 mgd, or about 42% of the total sewage of the city. Under construction are two major sewage treatment works and one minor works. The two major projects are Owls Head (capacity 165 mgd) and Hunts Point (capacity 120 mgd). The minor project is the Twenty-sixth Ward Plant (capacity 60 mgd). These are a part of the New York City sewage treatment program (25), costing $200,000,000.

The keel has been laid for a new sludge vessel (total cost $1,158,000) to be completed in 1951.

1951 Operation Data for New York City.—The city owns seven modern plants, and six old plants, the latter primarily equipped for screening and chlorination. In 1950, these plants removed solids at the rate of 327 tons per day; and they produced sludge gas at the rate of 1,162,000 cu ft per day, which produced power at the rate of 49,500 kw-hr per day. Sludge dumped at sea totaled 68,921 dry tons, and the weight of air-dried sludge totaled 8,075 dry tons. A total weight of 2,046,480 lb of wet scum was sold for a total sum of $5,901.90. The cost of treatment, per million gallons, was $22.56. The amounts of sewage treated by the four methods used are as follows:

Treatment	Sewage treated, in mgd
Activated sludge process	290
Chemical precipitation	47
Plain sedimentation	30
Fine screening	24
Total	391

Boston.—In a voluminous report, C. A. Maguire, M. ASCE, and Associates (27) review the necessity for, and design capacity of sewers and appurtenant works for relief from the pollution of Boston Harbor and its tributaries by the overflow of untreated sewage. A joint plan is proposed, which for the first time provides for the collection and disposal of sewage from the Boston Main Drainage District in addition to the collection and disposal of sewage from the North and South Metropolitan Sewerage Districts. By the use of jointly operated works, certain maintenance and operating costs can be eliminated, especially that of pumping sewage and storm water at three stations. The project has been approved (28) and sewage treatment will be given at Deer Island, Massachusetts. Thus, all the treatment facilities for Boston and the metropolitan area will be under the Metropolitan District Commission. The project includes a relief sewer on both sides of the Charles River Basin and a covered detention basin on the south side of the Charles River for the reception and chlorination of occasional sewage overflows into the Charles River Basin.

The Nut Island sewage treatment works is expected to be in operation late in the fall of 1951. However, the mechanical screens are now in operation, with chlorination treatment on a temporary basis.

Los Angeles.—The Los Angeles project (29) was built almost entirely as recommended by the firm of Metcalf and Eddy in 1944 (30). The plant is located on a 75-acre site, and is designed to treat the sewage of a population of 3,000,000 with an average dry flow of 245 mgd, and a maximum of 420 mgd. The submarine outfall (discharging 1 mile offshore) was put in service on September 2, 1949. The headworks, effluent outfall connections, and sewage disinfection plant were completed early in 1950 and set in operation on May 15, 1950, about one half the flow receiving primary treatment. By September 15, 1950, all the flow received primary treatment. The entire plant went into operation on March 19, 1951, including the high-rate activated sludge treatment plant. The excess activated sludge is digested, elutriated, conditioned with ferric chloride, dewatered on vacuum filters, and heat-dried in flash dryers. Storage for 2,200 tons of dried sludge is provided. The plant has no railroad facilities, but will be served by trucks.

As a result of primary treatment followed by chlorination, the quarantine on the beach extending on either side of Hyperion was reduced from 11 miles to 4 miles. Since June 24, 1951, there has been no bacterial pollution on the beach. The quarantine on the beach of Santa Monica was entirely lifted by the California State Board of Health on July 24, 1951.

The first year of operation is budgeted to cost $1,287,845 and to require 245 employees. The sale of sludge is estimated to produce an income of $210,000.

Reports.—Several reports on projects—either proposed or on which construction is about to begin—have reached the committee. These reports concern the following: The Allegheny County Sanitary Authority in Pennsylvania; the Blackstone Valley Sewer District in Rhode Island; the Middlesex County Sewerage Authority of New Jersey; Miami, Fla; San Francisco, Calif.; Santa Clara and San Jose in California; Seattle, Wash.; Tacoma, Wash.; Portland, Ore.; Tampa, Fla.; and Wilmington, Del. In some cases, the work is nearly completed.

Allegheny County Sanitary Authority.—The plans for intercepting sewers, pumping stations, and primary treatment plant are now under way. A novel method of sludge handling by flotation and incineration has been proposed.

Blackstone Valley.—The Blackstone Valley Sewer District Commission (31) program for intercepting sewers, pumping stations, and temporary chlorination facilities was completed and in operation in 1951. The Bucklin Point primary treatment plant, now under construction, should be completed in 1952. Part of the intercepting sewers and the chlorination facilities are now in use.

Miami.—Plans are in preparation for interceptors, pumping stations, force mains, treatment plant, and ocean outfall for the City of Miami. The treatment plant will be a high-rate activitated sludge plant located on Virginia Key across Biscayne Bay from the city. The pollution in Biscayne Bay was investigated (32) by David Bryon Lee.

Middlesex County Sewerage Authority.—The abatement of the pollution entering the Raritan River in New Jersey has been undertaken (33) by the Middlesex County Sewerage Authority. Essentially, the program involves about 25 miles of trunk and branch interceptors and force mains, a chemical precipitation plant, and a 2-mile outfall into Raritan Bay. Approximately 30 participants are expected to join in the program, half of whom will be industries (34) connected directly to the trunk sewer. The effluent of the treatment plant will be chlorinated and the sludge will be barged to sea.

Nassau County, New York.—Construction will be completed during the fall of 1951 on a new activated sludge treatment plant for Special District No. 2 in Nassau County. The plant is designed for a population of 236,000 and for an average sewage flow of 27 mgd. The district has a population of 500,000, of which about 75,000 persons are now served by sewer systems presently discharging into four village-owned plants which will be abandoned when the new plant is placed in service. Planning is in progress for sewer systems in several newly formed "collection districts." The cost of the entire program for sewerage and sewage disposal is estimated to approach $100,000,000, of which about $7,500,000 is for treatment, $15,000,000 for trunk and outfall sewers, and the remainder for service or lateral sewer systems.

East Bay Municipal Utility Districts.—The sewage disposal project for Special District No. 1, comprising the cities of Oakland, Berkeley, Alameda, Piedmont, Albany, and Emeryville in California was about 93% complete in August, 1951, and should be in operation on October 15, 1951. Completion was delayed by serious difficulties in the deliveries of equipment requiring copper in its manufacture.

San Francisco.—The program of providing sewage treatment for all the area east of Twin Peaks, California, which is not served by sewage treatment works built in connection with the Richmond-Sunset Works, is nearing completion. This consists of the North Point sewage treatment works (63 mgd), the Southeast sewage treatment works (30 mgd), a sludge force main from the North Point plant, and sludge digestion units adjacent to the new Southeast works. These works should be in operation in September, 1951. Both are equipped with preaeration (from 0.15 cu ft per gal to 0.20 cu ft per gal). The digested sludge will be elutriated and dewatered on vacuum filters and heat-dried in flash dryers.

Santa Clara and San Jose.—Plans for the sewage treatment work at San Jose have been completed, and the equipment has been purchased. The works include primary treatment and oxidation ponds (1,750 acres), sludge lagoons, and a recirculation pumping station. The estimated cost of the project is $4,500,000.

Seattle.—Since the report in 1948 by Abel Wolman, M. ASCE (35), the City of Seattle has abandoned the practice of disposing of raw sewage through numerous deep-water outfalls into Puget Sound. Investigations of the Washington Pollution Control Commission and the City of Seattle have shown that these outfalls, extending into 40 ft of water along the principal shores, have been unsatisfactory. Bathing beach areas were badly contaminated by sewage that rose to the surface and formed a field which was carried to the shore by incoming tides.

The present plan divides the city into four districts, each to be served by primary treatment (flocculation and comminution) and chlorination. In one area only, trial is to be made with preprimary treatment and chlorination and pumping into 80 ft of water. Primary treatment can be added later if needed.

Tacoma.—At Tacoma, Richard G. Tyler, M. ASCE, has prepared a supplementary report (36) confirming the earlier recommendations of C. S. Seabrook and Mr. Tyler (37) that raw sludge after chlorination be discharged into Commencement Bay. Tacoma is reported to have under construction a primary treatment and chlorination plant, estimated to cost $1,500,000, and designed to serve a population of 100,000, of which 60,000 reside on the south side of the city. The rest of the city presently discharges sewage through various outlets into Commencement Bay, which is a branch of Puget Sound. Some of these outfalls have been extended into deep water. A few are said to be operating successfully where the contributing population is small, but others are unsatisfactory, as at Seattle.

Portland.—The Portland sewage treatment works is essentially completed and went into limited operation in August, 1951. Because the Columbia River, into which the plant effluent discharges, has a very large flow, seldom going below 100,000 cu ft per sec and occasionally ranging from 150,000 cu ft per sec to 200,000 cu ft per sec in summer, the situation is unique, and from a strictly economic viewpoint, the degree of sewage treatment required is still under scrutiny.

Tampa.—The construction at Tampa (38) on July 15, 1951, was about 70% completed. The system includes intercepting sewers, pumping stations,

and treatment by sedimentation and chlorination, with sludge digestion and air-drying. This system probably will be in operation before the end of 1951. The project has been financed entirely from the sale of $12,000,000 of sewer revenue bonds. The construction cost is estimated at $9,500,000. This project included certain sewer improvements and rehabilitation of the old sewer system. Operation, maintenance, and debt service are to be paid only from service charges, ranging from a minimum of $1.50 per month, with an over-all average of about $4.00 per month.

Wilmington.—The plans for the sewage treatment program at Wilmington are reported (39) to be completed and construction has begun on intercepting sewers, pumping stations, force mains, siphons, and underwater piping. Wilmington has arranged to receive the sewage of Newcastle County, Delaware, for treatment.

Enlargements of Existing Plants.—Among the existing plants that have been rehabilitated or enlarged in the post-war period are those of Atlanta, Ga.; Baltimore, Md.; Houston, Tex.; New York City (Wards Island); Washington, D. C.; and the County Sanitation Districts of Los Angeles County in California.

Atlanta.—Three plants using Imhoff tanks and trickling filters were constructed at Atlanta in the period between 1910 and 1914. Because of the growth of the city, two plants (Peachtree Creek and Proctor Creek) were abandoned in 1938, and the outfall sewers were connected to a single treatment plant that consisted of a primary treatment with separate sludge digestion (45 mgd), known as the Clayton plant. Provision was made for chemical precipitation if needed seasonally but the equipment has not been used. During the summer chlorination is used.

At the Entrenchment Creek plant (originally 5 mgd), the old Imhoff tanks were converted to mechanically cleaned clarifiers in 1938, and provision was made for separate sludge digestion. The old trickling filters were kept in service, with additions to increase the capacity to 14 mgd. A preaeration (30-min) basin was installed at the head of the plant, which has been in service for some 13 years. The sewage contains considerable industrial waste, which tends to form a floc most of the time. After preaeration, considerable flocculated material is evident in the sewage. This material readily settles in the clarifier.

Baltimore.—The Baltimore sewage works were discussed in the last report of this committee (7). In the fall of 1950, a sludge-drying plant with flash dryers (from 60 tons to 75 tons of dry solids capacity) was placed in construction. It has a 350-ft stack to dissipate moisture, odors, and residual dust. This project is estimated to cost approximately $2,000,000 and should be in operation in the spring of 1952—heat-drying digested sludge.

Houston.—In 1947, the city was operating seven sewage treatment works. Since the report was made by the firm of Greeley and Hansen, and J. G. Turney, M. ASCE (40), the new activated sludge plant (20 mgd) at Simms Bayou was completed and put in operation, about the middle of 1948. Three of the old plants were then abandoned. The North Side works (activated

sludge) were enlarged from 18 mgd to 30 mgd, and went into service about the middle of 1950.

The Houston sludge disposal plant (41) went into service in August, 1950, for the purpose of dewatering and heat-drying activated sludge for sale to commercial mixers. The sludge is handled at the North Side plant, to which sludge is pumped through a 7-mile force main from the Simms Bayou plant. The lagoons that previously operated at the rate of 100 tons of dry solids per acre-foot per year will continue in use for peak loads. Natural gas is used for heat-drying and ferri-floc for conditioner, although at times a chlorinated ferrous iron that is made from local waste is also used.

New York City.—The Wards Island plant has been modified within existing structures, increasing its capacity to 240 mgd (42). This activated sludge plant went into service in October, 1937, with a design capacity of 180 mgd. In 1947, the average flow received was 226 mgd, with a maximum of 250 mgd.

In the original design, the preliminary settling tanks had a detention period of 1 hr, and the aeration tanks had an aeration period of 5.25 hr, with one tank out of service and an average sludge return of 25% (by volume) of the sewage flow. The final settling tanks had a capacity of 1,000 gal per day per sq ft at 125% average flow, with two tanks out of service. The principal changes are: (1) The incorporation of step-aeration in flow handling; (2) the construction of new distribution channels; and (3) the rearrangement of the final settling tanks as to influent conduits, baffling, and effluent troughs.

These changes have altered the current pattern and will enable the rehabilitated plant to provide a suitable effluent with a 4-hr detention period, when operated as a conventional activated sludge plant or under the step-aeration procedure. Furthermore, modifications in the return sludge piping have permitted operation under the high-rate method. In this operation, only half of the aeration tanks are used. Parallel operation using these three types of treatment has been carried out in the four separate batteries of the Wards Island plant.

Washington, D. C.—The Guggenheim demonstration plant was operated on the effluent of the sewage treatment plant of the District of Columbia until November, 1949, when the experiments were concluded (43). In May, 1950, this pilot plant was converted to a "high-rate aeration" type of treatment.

Additional sedimentation and sludge digestion tanks have been completed to provide a 2-hr displacement period for settling for a sewage flow of 175 mgd. For the fiscal year that ended June 30, 1950, the flow averaged 160.1 mgd, somewhat lower than the average of 171.4 mgd for the previous year. Sludge digestion capacity now totals 1,700,000 cu ft, or 1.75 cu ft per capita for a population of 975,000. A contract has been awarded for sludge-drying equipment and incineration equipment of the flash-drying type, comprising three units, each with a capacity for evaporating 12,000 lb of water per hr. The sludge cake will be burned during the winter; and in summer it will be dried for sale as a fertilizer base. Chlorinating facilities are being designed for use in the summer, and a high-rate activated sludge plant is planned for the removal of approximately 68% of the B.O.D. from the settling tank effluent,

during periods of low flow in the Potomac River, usually the 4 to 6 summer months.

Sanitation Districts of Los Angeles County.—A M Rawn, M. ASCE, reports that 15,400 ft of the 12-ft tunnel which the sanitation district is constructing parallel to, and about 150 ft east of, the existing 8-ft tunnel is entirely completed. This tunnel is to extend to a connection with the outfall pipes at White Point. Of the remaining 17,130 ft of tunnel to be completed, about 2,000 ft has been excavated. The outfall line from the sanitation district plant to White Point is being constructed in four sections, beginning at the plant. As each section is completed, it is connected laterally to the existing 8-ft tunnel. This procedure will adapt the outfall to increasing flows until 1955, when the tunnel will be completed. With the two tunnels and outfall, a combined capacity of 300 mgd is expected.

Increase in Number of Sewage Treatment Plants.—The USPHS reports (3) that the number of sewage treatment works in the United States has increased from 6,058 in 1948 to 9,300 in 1951—of which 6,700 were municipal and 2,600 industrial.

Operation

Effect of the Economic Cycle on Operation.—The cost of the operation of sewage treatment works has been steadily rising since 1940 because of the increased cost of labor, fuel, power, and various supplies. A comparison of operating costs and maintenance costs has been made for New York City and The Sanitary District of Chicago (Table 1) for the 11 years from 1940 to 1950. In both cases there has been a steady rise since 1943. The New York sewage treatment works treat 500 mgd. The Chicago works treat an average of 1,100 mgd. The annual sewage treatment costs in New York between 1943 and 1950 increased to 2.20 times the 1943 cost. In Chicago, the cost increased during the period from 1943 to 1949 to 1.64 times the 1943 cost, as compared with 1.77 times the 1943 cost for the same period in New York.

TABLE 1.—Cost of Operation and Maintenance for Sewage Treatment Works of New York City and of the Sanitary District of Chicago from 1940 to 1950

Year	Cost per Million Gallons, in Dollars	
	New York[a]	Chicago[b]
1940	10.52	10.08
1941	10.13	10.59
1942	10.62	11.33
1943	10.23	11.35
1944	12.09	11.88
1945	12.48	11.99
1946	13.27	13.42
1947	15.85	15.19
1948	16.50	17.47
1949	17.71	18.62
1950	22.55	23.50

[a] From 1950 Annual Report (25). [b] From Annual Audit by auditor appointed by State of Illinois.

An increase in the cost of operation is reported (44) at Toledo, Ohio, having risen since 1934 to an amount, in 1950, that is 2.3 times the 1934 cost. The cost in 1940 was practically the same as that in 1934.

The Buffalo (N. Y.) Sewer Authority (45) also reports a steady upward rise in the cost of operation from 1943 to 1950, with an increase of about 55%.

Fine Screens.—In recent years, the use of fine screens has been restricted to the treatment of industrial wastes, either independently or in connection with municipal sewage works. However, at Port Jervis, N. Y., a fine screen has been installed following Imhoff tanks and ahead of high-rate trickling filters.

Preaeration.—F. C. Roe noted (46) that in 1950 preaeration was used in ninety-one plants in eighteen of the thirty-three states reporting. From data collected, he concluded that preaeration is helpful in odor control and the prevention of septicity, in grease separation, in grit separation, in the removal of suspended solids (by increased flocculation), and in the reduction of oxygen demand. U. T. Mann (46*a*) has pointed out that most older preaeration units use far more air than Mr. Roe has indicated as being required (between 0.05 cu ft per gal and 0.15 cu ft per gal).

Preaeration is a subject that is freely discussed in general without much fundamental data. The earliest scientific appraisal of the effect of aeration was made by W. M. Black and Mr. Phelps (47) in 1911. So-called preaeration may be divided under several different uses: (*a*) For hydraulic reasons in comparatively large channels, to secure uniform distribution of flow (with a flat water surface slope) to various tank units, as in an activated sludge plant; (*b*) to reduce odors in stale or septic sewage arriving at a treatment works; (*c*) to increase grease removal; (*d*) to increase flocculation prior to sedimentation; and (*e*) for agitation, as in a grit chamber, to assist in cleaning the sand particles to be deposited.

For hydraulic reasons, the use of aerated channels was introduced in the activated sludge plant of The Sanitary District of Chicago at Maywood, Ill., around 1920, and was adopted later in works of the Milwaukee Sewerage Commission, the North Side works (Chicago), Wards Island (New York City), and other New York City plants.

The use of aeration to reduce odors in a stale or septic sewage was discussed (48) by the late George W. Fuller, M. ASCE, in 1911 and later in connection with the design of the long intercepting sewers of The Sanitary District of Chicago, in which the introduction of air was deferred until the need was demonstrated.

Preaeration is provided in recent designs for Miami, Terre Haute, and Bucklin Point (Blackstone Valley Sewage District Commission), and in works constructed at Los Angeles (Hyperion).

There is little evidence available concerning grease removal in most of the larger sewage treatment works. However, at the works of The Sanitary District of Chicago, little grease is found at the North Side or Calumet works. The small amount of grease arriving at the West-Southwest works from packinghouse wastes is removed in the preliminary settling tanks.

Most of the grease salvaged from the New York City plants is captured on the primary settling tanks. However, at Bowery Bay and Jamaica, substantial quantities of grease are recovered from channels or final settling tanks following aeration tanks.

At Greenville, S. C., the original sewage works received domestic sewage and considerable textile waste. The works included an aerator for pretreatment (2-hr period). Very little grease was found, and the improvement in

settling and B.O.D. removal effected by preaeration appeared to be only from 5% to 6%. Recently, in enlarging the works, the preaeration unit was abandoned.

However, in sewage mixed with industrial wastes carrying grease (particularly from packinghouses) in the south St. Paul (Minn.) (49) treatment works, grease removal units were installed but were seldom used because aeration at the influent end made the grit chambers effective grease removal units. At Tifton, Ga., the waste from a meat-packing plant is given pretreatment before combining with the city sewage. The pretreatment consists of a small settling tank to remove grit, followed by a mechanical aerator unit (45-min period), provided with a skimming weir. The packinghouse waste is reported to contain grease in the amount of 687 ppm, of which 85% is removed by the aerator or flocculation unit. Approximately 50% of the B.O.D. is also removed.

There is some evidence that air for flocculation ahead of primary settling tanks may be helpful. At the Entrenchment Creek plant (Atlanta), a preaeration unit (30 min) was provided ahead of the settling tanks. Because of the presence of industrial wastes, considerable flocculation occurs. The flocculated material readily settles in the clarifier. At Coney Island (New York), air for flocculation has been considered to replace the mechanical flocculators, because of the high maintenance cost of mechanical devices.

So far as can be learned (50), air diffusers are used for grit separation in six plants in the United States, of which Columbus, Ohio, was the first (51).

In general, preaeration on ordinary domestic sewage apparently is not common practice in an original plant design, in the absence of industrial wastes carrying grease. For industrial wastes from packinghouses or for sewage containing such wastes, a short period of aeration may be worthwhile.

There is considerable opinion expressed (52) about the advantage of preaeration, but as yet there is very little conclusive proof of such an advantage. Maybe it has an effect akin to flocculation of raw sewage. At present, from 30 min to 45 min seems to be the period considered. Whether flocculation will do the same work at less cost has yet to be determined.

In the field of industrial wastes, Fred S. Gibbs, A.M. ASCE (53), claims that, in treating industrial wastes, apparatus is available to provide chemical treatment, aeration, flocculation, flotation of solids, and downflow of clear liquid, whereby a clarified liquid overflow is obtained with removal and discharge of floated solids. A pilot plant apparatus (54) has been tested, using wastes from a paper board mill, a toilet tissue mill, a glue works, and a laundry. Full-scale plants have been installed on a paper plant and a soap works.

Diffuser Plates.—A special committee of the Federation of Sewage and Industrial Wastes Associations has prepared a manual on diffuser plates, which is now being processed for publication (Norval E. Anderson, M. ASCE, chairman). The subject was written up in the last report of the ASCE committee (7). In the meantime, a number of cities have purchased plates for new plants and for replacements. At New York City, high-pressure jet washing has become the established procedure of cleaning plates, with the occasional use of oxy-acetylene spalling in tanks in which jet washing appears inadequate. At

Wards Island, where the most clogging occurred, new plates have been purchased and are being held until it is deemed that the existing plates can no longer be cleaned by jetting or spalling. In 1950, 42,000 plates were purchased: One half are Filtros, permeability 25; one fourth are Carborundum; and one fourth Norton plates, with permeability ranging between 50 and 80.

In addition to the plate diffusers at Wards Island, in 1949, tube diffusers were installed in the influent channels of the modified final settling tanks. Of the four batteries in the plant, three were equipped with ceramic tubes and one with saran-wound tubes.

At the North Side works (Chicago), in 1950 and early 1951, new plates with a permeability of 80 were installed in all channels and aeration tanks. Only one row of plates was installed instead of replacing the original two rows in the aeration tanks. The original plates had served for 23 years with very little attention, but were beginning to show signs of serious clogging. At the Calumet works (Chicago), in 1950, new plates of a permeability of 80 were installed in one row in each of six tanks. At the West-Southwest works (Chicago) the new Battery C was placed in service between November 16 and December 21, 1949. Cast iron boxes holding six plates were placed normal to the tank wall. There were 2,652 plates in the influent half and 2,076 plates in the effluent half of each tank. Plates with a permeability of 80 were used in seven tanks, and with a permeability of 120 in one tank. Air mains were embedded in concrete at the top of the tank walls. The mixing channel and influent channel were equipped with swing diffusers (with ceramic tubes). The return sludge channel was equipped with slotted brass tubes on fixed headers. The new "dustube" air filters were in service on July 10, 1951.

Activated Sludge.—The trend in New York City is toward the extension of the high-rate activated sludge process, with resultant savings in initial operating cost (25). The Jamaica plant has been operated with the high-rate treatment for several years with satisfactory results. One half of the Wards Island plant is also operating on the same basis. It is probable that the plants at Bowery Bay, 26th Ward, Rockaway, and Owls Head, will operate in a similar manner. The Owls Head plant (160 mgd), with no primary sedimentation and a 2-hr aeration period, is the boldest example of the short-period treatment thus far planned. This plant is scheduled for operation in early 1952, as is also the Rockaway plant (15 mgd) of similar design.

Final Settling Tanks (Activated Sludge).—Since the last report of this Committee (7), particular attention (in the operation of New York City works) has been given to the behavior and improvement of final settling tanks for the activated sludge process. Further studies have been made of the disturbing influence of density currents, of the effect of changes in chloride content incidental to sewage collecting systems located along tidal waters, and of temperature effects. These studies have been translated into modifications of final tanks at several plants. At the Bowery Bay plant, tanks were arranged to bring the sludge outlet to the overflow end of the tanks. Later, the Wards Island final tanks were modified to supply the influent at one end, with sludge withdrawal in the center and with effluent take-off at the inlet end. Outlet weirs were also provided at the distant ends of the tanks.

At the Tallmans Island plant, half of the final tanks are now provided with effluent weirs near the inlet and sludge withdrawal at the far end. The other half of the final tanks, containing four parallel passes each, have been modified to provide inlet parallel flows in one pass of each tank, sludge withdrawal at the far end with return flow in three passes (a so-called U-tank). The analytical results show appreciable improvement in effluent over the original Tallmans Island tanks, with the U-type tanks somewhat the better of the revised structures. The 26th Ward plant, at which secondary treatment started March 29, 1951, has incorporated two changes into the original conventional final tanks. First, the effluent weirs were modified during construction to take off at the inlet end of the tanks. However, recently the four passes were modified by changes in baffling to give two parallel inlet passes and two parallel effluent passes (U-tank) with sludge withdrawal at the half point. At Bowery Bay, in the course of construction, the final tanks are being further modified to permit tandem flow through two of the four passes, followed by parallel flow through two effluent passes. The Hunts Point plant, under construction, has been modified to provide influent flow through one of four passes, followed by parallel flow through three passes. These modifications, although different because of the adaptation of existing structures, have the common objective of minimizing stratification, disturbing density currents, and moreover, shortening the time the activated sludge is held in the final tanks.

Activated Sludge.—Two special investigations have been made on certain phases of the activated sludge process: H. Heukelekian, H. E. Orford, and R. Manganelli (55) have studied the factors affecting the quantity of sludge produced under laboratory conditions and have indicated that the factors inducing greater sludge accumulation also induce bulking; and C. E. Keefer, M. ASCE, and J. Meisel (56) have studied activated sludge to determine the effect of sludge on oxidizing capacity, efficiency and performance under various operating conditions, and the effect of pH of sewage on the activated sludge process. Messrs. Keefer and Meisel have concluded that the best results (as judged by the oxygen consumed test) were at pH 7.0 to 7.5, although removals were almost as good with pH values ranging from 6.0 to 9.0. Raising or lowering the pH on either side of neutrality greatly reduced the sludge index.

Concentration of Excess Activated Sludge.—In New York City in 1950, the excess activated sludge at Wards Island as pumped to the storage tanks averaged 2.72%; at Tallmans Island, the excess activated sludge as pumped to the digesters averaged 2.53% solids. In 1950, operating on short-period aeration, Bowery Bay averaged 4.50% solids pumped to the digesters. At Jamaica, also operated on short-period aeration, 6.14% solids went to the digesters. These percentages represent the result of concentrating the activated sludge before admixture with primary sludge and before decanting. The subject of the concentration of sludge has been investigated extensively in order that the digester capacities may be used more efficiently, and the volume of sludge carried to the sea may be reduced. The increasing proportion of sludge from high-rate treatment is very helpful.

W. Rudolfs, M. ASCE (57), has experimented on the concentration of activated sludge by compacting and flotation, and has described the effect of various chemicals.

Sludge Processing

Control of Bulking by Use of Digested Sludge.—Digested sludge and digester overflow to control bulking activated sludge were tried at Peoria, Ill., by L. S. Kraus (58). At the present time the Pacific Flush Tank Company is the exclusive licensor under the Kraus process, which is covered by United States Patent 2,517,792 (59). The process has been used in Peoria (54) for many years and is incorporated in the Northeast plant at Philadelphia, at the Durham (N. C.) North Side plant, at two plants under construction, and is in the plans for at least three other projects.

In 1950, the existing North Side works, at Durham, were provided with a new distribution chamber and weir control chamber to utilize the Kraus process. It is reported that, since the Kraus process was placed in operation, the sludge index stabilized below 200, ranging from 100 to 150, whereas previously it had varied from 200 to 700. The effluent was clearer and the degree of treatment more consistent. The waste-activated sludge now has an average solids content of between 2% and $2\frac{1}{2}$% as pumped to the digesters, compared with a former average of from 1% to $1\frac{1}{2}$%.

Effect of Digestion on Sewage Sludge.—Since the investigation by Mr. Rawn and E. J. Candell (60), the feasibility of chlorination of raw and digested sludge has been examined by Mr. Tyler, G. T. Orlob, J. M. ASCE, and Fred W. Williams (36) (61) on the theory that, if sludge can be chlorinated satisfactorily and economically, the possibilities for its discharge into receiving waters are greatly expanded. They have concluded that sludge can be sterilized by adequate prechlorination of the sewage before settling. Both raw and digested sludge can be chlorinated satisfactorily after having been broken up in a laboratory blender. The economic effect on treatment plant design has not been discussed by these men. Further study would seem to be required.

Sludge Lagoons.—Owing to an unexpected winter loading, the lagoons of the West-Southwest works (Chicago) developed considerable odors, early the following summer, which occasioned complaint. So far, no effective deodorant has been found.

Sludge Digestion.—T. C. Schaetzle has reviewed (62) the subject of sludge digestion, control of operation, digestion balance, control of temperature (at Akron, Ohio, 95° F is favored), control by pH (6.8 to 7.4) rather than by alkalinity, judicious liming, and supernatant control. In the sixth and last article in a series, T. R. Hazeltine, A.M. ASCE, has discussed (63) digestion tank troubles, such as odors, scum, supernatant liquor, and foaming, with suggestions for betterments.

In sludge digestion installations, there is a trend toward the use of external heat exchangers and also toward high-capacity mixing with intermittent operation of the mixers. A spiral heat exchanger has been installed at Tallmans Island (New York City) in two units, with 436 sq ft of heating surface to deliver 1,800,000 Btu per hr. From 1947 to 1951, thirty-eight plants have been equipped with this type exchanger. The largest example of the high-capacity mixer type is at Hyperion (Los Angeles), where twelve units, each 111 ft in diameter, are served by three mixers of 10 hp each. A total of seventy-one plants in the United States are using this type exchanger.

In New York City, an external heater was installed for one of the digesters at the Harts Island works when the internal heating coils failed. At Tallmans Island, external heaters have been installed, largely because, in using the four digester units in combinations of primary-secondary digesters, there was difficulty in providing sufficient heat for the primary sludge. At the 26th Ward plant, the digesters, originally equipped with internal heating coils, have been changed so as to use external sludge heating because of leakage in the old coils and possible difficulty in using the digester units in any desired combination for primary-secondary digestion.

Elutriation.—A. L. Genter, M. ASCE, reports that the year 1951 will find twenty-six elutriation plants, serving a population of about 9,500,000, in operation in the United States and Canada. Seven others are under construction. In addition, there are several foreign elutriation plants. In England, the large Maple Lodge sewage works of the Colne Valley is nearing completion (64); in Holland, two plants are serving Amsterdam; and in Germany, at Baden-Baden, the novel sludge disposal plant designed by Franz Poepel (65) is now in successful operation. Like the Richmond-Sunset plant in San Francisco, the Baden-Baden plant is equipped to use elutriation between stages of digestion for increasing the efficiency of digestion space, and for storage after secondary digestion, to increase the efficiency of the sludge-drying beds. Mr. Poepel states that experimental work conducted at the Hamburg-Bergedorf treatment plant and at Stuttgart in Germany shows that elutriated digested sludge dewaters on sludge-drying beds in half the time required for drying unelutriated digested sludge.

The value of elutriation has grown from that of saving coagulating chemicals in mechanical dewatering of sludge solids (particularly digested solids) to saving digestion space and disposal costs. Most of the progress in this growth received initial recognition and became permanent operating practice in the Richmond-Sunset treatment plant at San Francisco (66). In the original application, elutriation of the digester supernatant, as well as bottom sludge from digesters, was used to eliminate the cycle resulting from recirculating digested solids after completed digestion, and to save chemicals used for dewatering. This was put into practice at the Richmond-Sunset plant in 1940 and proved successful (66). It is being installed at the Southerly plant (Cleveland, Ohio) and was incorporated in the Hyperion plant (Los Angeles).

The other major development in elutriation adopted at the Richmond-Sunset plant has been the adoption of intermediate or inter-stage elutriation (66). This consists essentially of single-stage elutriation of the entire liquid contents of a primary active digestion tank and transfer of the concentrated washed solids to secondary digestion storage. Experience at the Richmond-Sunset plant confirms the advantages claimed for this new development. If the percentage of volatile matter left in the digested sludge is 50% or less, the elutriated sludge stored in the secondary digesters may become so heavy that mechanical sludge collectors may be necessary for removal of the sludge from the secondary digestion tanks.

K. Fraschina (66) concludes that

> " *** the elutriation system at the Richmond-Sunset plant has proven itself in action operation to be a very valuable and necessary part of the plant treatment processes. It has not only fulfilled design expectations, of reducing coagulant requirements and producing sludge with uniform coagulating and dewatering properties, but also has been utilized effectively in removing suspended solids from digester supernatant liquor. It has increased the flexibility of operation of the two-stage digestion system and shows promise of increasing its capacity."

Gas Engines.—The most striking development in the gas engines of the New York City works is the supercharged feature of the six dual-fuel 1,300-bhp units furnished for the Owls Head works. The Hunts Point plant will have four 900-hp units driving either generators or blowers. According to H. P. Hayes (67), the trend toward supercharged engines is becoming more pronounced with each passing year, as an economical means of increasing engine output, without any harmful effects on the life of the engine.

Plant Equipment.—Sewage plant equipment is described by F. L. Flood, M. ASCE (68), in a series of four articles, covering racks, comminutors, grinders, grit chambers, sedimentation tanks, and sludge digestion tanks.

Circular clarifiers are still very popular and continue to be installed.

Clarigester.—The Clarigester is an apparatus designed by J. F. Skinner, M. ASCE, in 1929 for the City of East Rochester, N. Y. Basically, it consists of a clarifier placed on top of a sludge digestion chamber. A United States patent, (No. 1,925,679) covering this invention, was issued to Mr. Skinner on September 5, 1933, and was assigned to the Dorr Company. Over 182 installations have been made, of which 129 are in the United States and possessions.

In a number of installations, the digestion chamber is heated to temperatures of from 85° F to 90° F, particularly in some 30 installations in Canada for the Royal Canadian Air Force during World War II. Apparently the heat requirements are approximately the same as for separate digesters, but outside fuel such as coal, oil, or even electricity, should be used for heating because of the unreliability of the digester gas in such small units. The sludge gas usually is burned in a waste gas burner.

Vacuator.—The vacuator is being used more extensively and is reported to have justified its installation in thirteen plants, of which three handle cannery wastes and one process mixed sewage and cannery wastes. The largest installation on cannery wastes is at Modesto, Calif. (handling 20 mgd). At Palo Alto, Calif. (5 mgd), where cannery wastes constitute 50% of the sewage flow, Robert P. Logan (69) states that, when the vacuator served as a primary unit, the removal of suspended solids of mixed sewage and cannery waste ranged from 28.9% to 45.5%, and removal from domestic sewage alone was 49.4%. An average of more than 60% of the solids removed were in the form of scum. On occasion, this removal increased to 80%.

At McAlester, Okla. (70), a vacuator treats a sewage flow of 0.5% mgd containing 200 ppm suspended solids and 160 ppm in B.O.D., and is reported to remove 45% suspended solids and from 24% to 25% of the B.O.D.

Dewatering and Heat-drying of Sludge.—A summary of heat-drying and incineration installations (prior to September 1, 1951) is given in Table 2.

There are more installations of the multiple-hearth furnaces than of the flash dryer, with a greater total capacity.

At Ashland and Piqua, in Ohio, liquid sludge from the sedimentation tanks is fed directly to the multiple-hearth furnace without vacuum filtration. At Ashland, H. Maxheimer reports that the solid content varies from 10% to 15%, with a volatile content (on a dry basis) of 70% to 75%. Natural gas is used as an auxiliary fuel.

TABLE 2.—HEAT-DRYING AND INCINERATION INSTALLATIONS IN THE UNITED STATES (1951)

Type of drier	Number of Installations			Total capacity, in dry tons per day
	Incineration	Heat-dried fertilizer	Under construction	
Flash	6[a]	9	9	1,343
Multiple-hearth	31	2[a]	4	4,860
Rotary		1		
Vacuum spray	1			

[a] Drying with provision for incineration.

Flotation of Sludge.—During the past years, various investigators have endeavored to find a way to float the solids in sludge, usually by the addition of chemicals and heat. Recently, John F. Laboon, M. ASCE, has developed a procedure for the concentration of raw sludge without the use of chemicals. A pilot plant handling 100,000 gal per day was in operation in the fall of 1950 and during 1951. The raw sludge is pumped into a plant for preaeration. The aerated sludge is then transferred to a vertical tower, hexagonal in shape, with Plexiglass windows. Four of the six faces are heated by vertical steam lines and insulated with Celotex.

The raw sludge is heated by steam before entering the tower, which is kept at a temperature of from 35°C to 37°C by steam coils. At the end of 24 hr, with a primary sludge having an initial solids content of 3.5%, the solids concentration at the top of the tank is only about 8%. This increases during the next 24 hr to about 13%. The tests indicate that the optimum period for holding the heated sludge in the tower is 5 days, during which nearly all the solids rise to the top and float in a scum blanket 2 ft thick (the exact thickness depending on original quantity and concentration of primary sludge containing from 18% to 20% solids).

At the end of the treatment period, the subnatant is withdrawn from the bottom of the tank and returns to the primary clarifier. The clarified effluent is discharged into the sewer. When a concentration tank is discharged, a thick black sludge emerges, and as the discharge continues, the subnatant clears somewhat and eventually becomes low in solids content, averaging 1,000 ppm.

The scum blanket drops to the bottom of the tower and is pumped into the incinerators. The concentrated sludge can be dewatered on a vacuum filter if

desired, by diluting it to a solids content of about 14%. The cake from the filter has a water content of from 68% to 70%. ,Filter efficiencies are possible, comparable to rates obtained with chemical conditioning.

Maintenance and Operation Problems.—At Buffalo, George F. Fynn and G. M. Scheller (71) found that sewage from a combined system of sewers deposits approximately 3 cu ft of grit per million gal in the grit chamber but grit enters the settling tanks nevertheless and finally lands in the digestion tanks. After operating for 13 years, one digester was drained, the concentrated sludge was liquified, and the accumulation was pumped out into a temporary lagoon.

Further problems of operation and maintenance are discussed by Morris M. Cohn, M. ASCE (72), and by LeRoy W. Van Kleeck, M. ASCE (73).

Chemical Treatment

Chlorination.—The essential public health need for chlorine under appropriate conditions is now widely recognized. Based on the 1948 survey of the USPHS (74), chlorination was used as a part of the treatment process in more than 1,307 sewage disposal plants in the United States. As the stream pollution abatement programs are completed, the demand for chlorine doubtless will increase. The application of chlorine in the treatment of industrial wastes also is becoming diversified. The need for chlorine in the treatment of sewage was recognized by the National Production Authority late in 1950. There remains the question of production.

Early in September, 1951, the Federation of Sewage and Industrial Wastes Associations published a manual entitled "Chlorination of Sewage and Industrial Wastes" (75), which reviews chlorination practice in the treatment and disposal of wastes from the earliest known applications. This supersedes the earlier report of the committee on sewage disposal of the American Public Health Association, Engineering Section (76) (long out of print) but fails to indicate the shortcomings of chlorination in situations in which evidence is conflicting or of minor weight. The references are not well arranged for easy use and are not identified by numbers in the text.

Chlorination of Sewage Effluents.—The use of chlorine in reducing the bacterial content in sewage treatment works effluent is increasing because it helps to protect bathing beaches or water supplies. At Detroit, Mich., in the 8-year period from 1941 to 1949, the average use of chlorine was 5,638,800 lb per yr, with a maximum annual use of 7,828,000 lb per yr. The maximum daily use was approximately 35,000 lb. The yearly average use in 1950–1951 was 4,197,090 lb because of a strike in the alkali industry in 1950.

At Los Angeles, in connection with screened raw sewage, about 36,000 lb per day were used. Since the Hyperion plant went into complete operation, the use has declined to about 26,000 lb per day and is gradually being reduced.

Buffalo (45), Cleveland (77), and plants of the North Shore Sanitary District, north of The Sanitary District of Chicago, also use considerable amounts of chlorine to protect the water supply and bathing beaches.

At seven of the New York City treatment works, the effluent is chlorinated for the protection of bathing beaches during the summer recreational months, using annually approximately 936 tons of chlorine.

According to Charles G. Hammann (78), interim sewage disinfection has been practiced in the Blackstone Valley project using chlorine in two interceptors having flows of 8 mgd (North) and 2.5 mgd (South) with permanent chlorine equipment for 6,000 lb per day, with minimum quantities of 430 lb per day (North) and 215 lb per day (South).

Chlorine Use on Industrial Wastes.—One of the most interesting developments in present chlorination practice is in the treatment of industrial wastes (which has markedly increased) since 1930. The subject is well summarized in a manual (75).

Recently, the Ohio River Valley Water Sanitation Commission research report (79) has focussed attention on the use of chlorine for oxidizing phenols in industrial wastes, indicating that chlorine, ozone, or chlorine dioxide can oxidize phenols. Each of these oxidants was tested on coke-plant waste in a 2-gal-per-min pilot installation at a Hamilton (Ohio) by-products coke plant.

Significant findings for ammonia-still wastes were: (1) Each oxidant reduced the B.O.D. more than 60%. (2) Chlorine treatment requires pH adjustment in the range between pH 7 and pH 10. Ozone and chlorine dioxide work best when added to waste at pH 11.5 with no further pH control. (3) Temperatures above 45° C in chlorination may cause chlorates, requiring heavier chlorine dosage. (4) Ammonia demand must be satisfied first if the necessary breakpoint potential is to be reduced in chlorination. The presence of ammonia has no apparent effect on ozone treatment or on chlorine-dioxide treatment. (5) Chlorination requires complete oxidation if chlorophenols are to be avoided. (6) Residual chlorine must be several hundred ppm in order to remove phenol or to reduce it to low concentration. Granular activated carbon will remove excess chlorine. Residual ozone or chlorine dioxide can be controlled to within less than 1 ppm, requiring no aftertreatment. (7) Chlorine adds chlorides to the waste in an amount equal to the dose; chlorine dioxide adds about 1.5% chlorides; ozone adds none.

According to B. F. Dodge and D. C. Reams (80), the oxidation of cyanide to less toxic cyanate by chlorine is considered the most satisfactory and cheapest procedure. The Michigan Water Resources Commission (81) found that chlor-alkali oxidation had the widest application.

J. Zymanski reports (82) that, at New Britain, Conn., the cyanide wastes in the sewage (which caused difficulty in the plant and complaint downstream) are now controlled at the sewage works by chlorination. The industries discharging pickling liquor are required to equalize the flow over 24 hr, rather than use batch dumping.

Chlorine Production.—Chlorine production (7) in the United States has risen from 40 tons per day in five plants in the year 1900 to more than 5,000 tons per day in fifty-eight plants in 1949. In 1951, the production is reported (83) to be running at the rate of 5,500 tons per day, with a possible increase in production capacity in the period 1951 to 1953 of a million tons per year.

The price in tank cars f.o.b. works was reported to range from $3.20 per 100 lb to $3.80 per 100 lb in 1951. Since 1940, the price of chlorine rose from $1.75 per 100 lb to $2.70, advancing only 154%, as compared with 205% for the commodity price index.

Chlorination of Raw and Digested Sludge.—As previously noted, Messrs. Tyler, Orlob, and Williams have investigated the chlorination of raw and digested sludge (61) and conclude that sludge can be sterilized by adequate prechlorination of the sewage before settling. Both raw and digested sludge can be chlorinated satisfactorily after disintegration in a laboratory blender. Although dilution seems to facilitate homogenization of the sludge, it does not increase the chlorination efficiency. The chlorine demand varies directly as the quantity of volatile solids in the sludge. The quantity of chlorine per capita for sterilizing sludge was approximately equal for both the raw and the digested sludge that was used. The chlorine absorbed varies directly with the dosage and time of contact. Chlorination of sludge decreases the pH and improves the settling characteristics. E-Coli seems to be more susceptible to chlorination than other organisms. Aftergrowths occur if the chlorine dosage is small but these decrease with increasing dosages.

Chemical Treatment of Sewage.—A few developments in this field have occurred since the last committee report (7). At Lebanon, Ohio, to obtain a higher degree of treatment, a chemical precipitation plant using lime was converted to an activated sludge plant in 1950–1951. This increased the removal of B.O.D. from 53% to 92% or more (84).

At Daytona Beach, Fla. (85), a novel chemical precipitation plant combines coagulation and settling in a single upflow apparatus. The coagulant is calcium carbonate sludge from a water softening plant. The plant has been in operation for a year, averaging 65.3% removal of B.O.D. on an average flow of 3.5 mgd, with a B.O.D. of 199 ppm in the raw sewage and 72 ppm in the effluent. The sludge is dewatered on a vacuum filter, producing a cake averaging 47.2% moisture.

Lime.—The National Lime Association offers two bulletins concerning trade wastes, one of which describes the use of lime in industrial waste treatment (86). The other compares the use of lime with the use of caustic soda and soda ash as acid neutralizing agents (87), and includes a bibliography covering sixteen industries. Furthermore, it issues bulletins on lime, its handling, application, and storage in treatment processes (88); on the principles of sewage treatment (89); on chemical lime facts (90); and on lime in agriculture (91).

William A. Parsons, J.M. ASCE, and Mr. Rudolfs (92) indicate the increasing use of pyrophosphate solutions as alkaline copper plating baths because they provide the desirable effects of complex metalling salts without the danger to personnel involved in the use of cyanide. The copper pyrophosphate plating baths rarely constitute a problem, as they are only infrequently, if ever, discharged. The wash waters which are discharged continuously may contain enough copper to be deleterious to aquatic life and biological sewage treatment processes. However, lime treatment will remove the copper.

Chemical treatment is proving helpful where trade waste is received and where waste is pretreated at the source, particularly if acid wastes needing neutralization are discharged.

At Bolivar, Tenn. (93), tannery wastes are dumped in lagoons every other week. Two barrels of anhydrous ferric sulfate are mixed in the feed channel with 750,000 gal per day of waste.

Sludge Bed Cleaning.—Mr. Rawn and W. F. Garber (94) recommend the use of field beds or shallow earth lagoons for air drying of digested sludge as being more efficient than the conventional underdrained sand beds. A tractor works the sludge to accelerate drying. A much lower cost of construction, maintenance, and operation is claimed, with greater output per year.

For removing sludge from air drying beds, W. E. Schlechty recommends a tractor loader (95). W. A. Sperry (96) saves labor in moving sewage sludge by the use of saddle-bag tractors. For the past 3 years, digested sludge from the Coney Island works (New York City) has been dewatered on about 20 acres of sand beds or lagoons in the undeveloped Marine Park in Brooklyn. Sludge is removed by bulldozer and tractor, and the air-dried sludge is utilized by the Department of Parks.

Sludge Drying Beds.—In measuring sludge drying bed performance, Mr. Haseltine proposes (97) units of pounds of solids applied per square foot per 30 days of actual use, rather than pounds of solids applied per square foot per year. He presents such results for fourteen plants. The solid content of sludge removed from the beds ranged from 62.8% to 24.5%. One plant (at Butler, Pa.) has glass-covered drying beds. Next to air temperature, the solid content of the sludge applied to drying beds is the most important factor influencing bed performance. The moisture content of the sludge as removed is the next most important factor. Addition of alum or activated carbon may promote faster drying.

Industrial Wastes

In the past 2 years, the interest in the treatment of industrial wastes has continued to increase, as various industries have undertaken to treat their particular wastes. Industrial waste conferences have been of value such as those held biennially at Purdue University, in Lafayette, Ind. (98), and the occasional conferences at the University of Washington, in Seattle (99). The American Petroleum Institute (API) has studied certain phases of the handling of oil refinery wastes, particularly the design of oil separators. For several years the American Steel and Iron Institute has investigated the handling of waste acid pickle liquor, without finding an economically practical solution to the problem. The National Council for Stream Improvements, Incorporated, is still actively studying paper wastes (100). The National Lime Association has also published various bulletins on the use of lime in the industrial waste field. The American Society for Testing Materials has recently entered the field by establishing a section for industrial waste study.

To aid in the abatement and control of industrial waste pollution, a National Technical Task Committee on Industrial Wastes, sponsored by the USPHS and the Water Pollution Control Advisory Board, was established in 1950 (101) (102) (103). It consists of about 30 members, with 250 technicians forming the working committees. Immediate tasks of the committee are: (*a*) Assembly of a source list of existing treatment and control practices; (*b*) listing of existing research activities on industrial wastes; and (*c*) enumeration of problems in treatment of industrial wastes.

Performance of a Gravity-type Oil-Water Separator Operating on Petroleum Refinery Wastes.—This separator at Whiting, Ind. (104), receives a flow vary-

ing from 61 mgd to 106 mgd. The total oil received by the separator varied from 2,800 bbl to 6,000 bbl per day, averaging 4,160 bbl per day. Of this waste oil, the recovery ranged from 93.1% to 98.4%, averaging 97.1%.

Chemicals from Fats.—A new plant of Armour & Company at McCook, Ill. (105) (106), contains a unique combination of processing units for the conversion of fats, oils, and fatty acids into various chemicals, such as crude glycerine, pure fatty acids (fractionated according to the length of the carbon chain), amines, and nitriles.

Pretreatment for Recovery of Usable Products.—S. Coburn (107) states that in some cases useful materials can be recovered from industrial wastes. In many cases these wastes contain no useful recoverable materials. Besides the technology of waste treatment, economics is also involved. Mr. Haseltine concurred, indicating that economics is important, including the value of the waste water itself.

Railroad Yards.—In connection with the clean stream program in many localities, attention has been required at railroad yards and shops for the inspection and maintenance of diesel engines or steam locomotives, not only for treatment of human sewage from the workers but also to prevent the escape of oil or other industrial wastes. In the larger municipal areas, such as The Sanitary District of Chicago and The Sanitary District of Milwaukee, the railroad shops and facilities have been connected to the nearest sewer system, usually with some pretreatment to remove oil or grit-carrying wastes. At the Enola, Pa., freight classification yard on the Susquehanna River, the Pennsylvania Railroad has placed in operation a modern industrial waste treatment plant (average flow 2 mgd; maximum storm flow 4 mgd) for removing oil and suspended solids from the waste water from the yard operation (108). The waste enters two primary settling tanks (total detention 30 min at 2 mgd), each equipped with a straight-line sludge collector, an oil skimmer, and a telescopic sludge drawoff valve. The effluent is dosed with lime and sulfate of alumina in a flash mixer (1.35), passing to a slow mixer (30-min detention) for flocculation, and thence to secondary settling tanks (2.3-hr detention). The final effluent goes into the river. The oil and sludge that are removed are placed in separate lagoons that are provided with decanting pipes, so that supernatant liquor can be returned to the flash mixer for retreatment. The most difficult wastes come from engine washing, in which a highly alkaline substance combined with oil is sprayed on the engines to prevent corrosion. This causes the plant influent to vary in pH from pH 5 to pH 11 during a day. The influent waste contains from 500 ppm to 1,800 ppm of oil. The effluent from the first tank contains 100 ppm of oil. The final effluent contains approximately 20 ppm of oil, which is less than the state requirement of 30 ppm. Normally 40 ppm of alum and 20 ppm of lime will give a satisfactory effluent. For about 4 hr every day, when engine washing is extensive, from 200 ppm to 400 ppm of alum (but no lime) are required.

Effect of Industiral Wastes on Sewage Works Operation.—There is a continually growing record of deleterious effects on sewage treatment resulting from various industrial wastes (109). Useful data are summarized in the manual of the Federation of Sewage and Industrial Wastes Associations (110).

The effect of metal wastes on sewage treatment plant design at Waterbury, Conn., is presented by R. D. Mitchell, A.M. ASCE, J. G. Cassanos, and D. A. Okun, A.M. ASCE (111). Waterbury is an important center of the brass industry in Connecticut. The metal industries of this city empty into the sewers quantities of acid and alkaline solutions containing copper and chromium. The water supply is soft (about 20 ppm alkalinity as $CaCO_3$). A sampling program indicated the presence of copper and chromium in excess of the amounts that could be tolerated by a plant with sludge digestion as a part of the treatment process. The effect of packinghouse wastes on the sewage of Topeka, Kans., is described by D. B. Kissinger (112).

The effects of industrial wastes on the municipal sewage works at Detroit are described (113) by Isadore Nusbaum under the following topics—acid wastes; inflammable and explosive wastes; high solids wastes; grease, oil, and tar; cyanides; phenols; and soluble oil.

Toxicity of Industrial Wastes to Fish.—Peter Doudoroff and Max Katz present (114) a critical review of literature on the toxicity of industrial wastes and their components to fish. The susceptibility of different species of fish to various alkalies, acids, and inorganic gases varies. Messrs. Doudoroff and Katz conclude that under otherwise favorable conditions pH values above pH 5.0 and ranging upward to pH 9.0, at least, are not lethal for most fully developed fresh-water fish. However, extreme conditions of pH are evidently undesirable and hazardous for fish life in waters that are not naturally so acid or alkaline.

C. W. Klassen, W. A. Hassfurther, and M. K. Young (115) studied the tolerance of small fish to plating wastes containing hexavalent chromium and found that over 50% of the fish survived 30 days in concentrations of chromium as high as 49 ppm.

Detergents.—The history and developments of detergents are outlined by W. W. Niven, Jr. (116), from the first synthetic detergent, produced in about 1860. The instability of soap in acid solutions and the insolubility of alkaline earth soaps provided the stimulus for the development of synthetic detergents. Mr. Niven indicates five general types, although hundreds of surface-active agents have been developed. Technically, a detergent is a cleansing agent and thus includes soaps and synthetic detergents. In laundering, there is interest in foams that persist at least several minutes, and form what the housewife calls suds. So long as adequate suds are maintained, the laundry operator knows that there is no deficiency of dissolved soap.

Effect of Detergents on Sewage Treatment.—Messrs. Rudolfs and Manganelli and I. Gellman (117) show the increase in the use of surface-active agents to be from 27,900,000 lb in 1941 to 184,442,000 lb in 1945. Walter E. Merrill (118) stated that, in small-scale experiments using up to 100 ppm of two detergents, there was found to be little, if any, effect on the sedimentation of domestic sewage. Mr. Rudolfs points out (118*a*) that this may be true for anionic materials, but that other types may aid in solids removal. Operating experience varies. At Massillon, Ohio, Richard F. Snyder (118*b*) reports that foam and froth create a nuisance. At Chicago, New York City, and Philadelphia, in the activated sludge plants, no deterioration of effluent is noted.

However, the increase in the amount of foam at the New York City activated sludge plants is causing concern as to the situation, should the present accelerated rate of sale and use of detergents continue. During the past year experiments have been conducted on various possible remedies for this situation. Mr. Rudolfs suggests that defoaming agents (sometimes called antifoam agents) are helpful, but Gail P. Edwards, M. ASCE (118*c*), considers them only moderately successful, because the defoamer loses its effectiveness as it passes through the aerator.

At Hyperion, Los Angeles (119), detergents caused a large "bubble bath" in the aeration tanks, and made walkways slippery. However, foam may cause operating difficulties. At Batavia, Ill., the aerators were concealed from view with foam from 8 ft to 10 ft deep, according to Frank W. Olson (120*a*). The foam may interfere with settling in the primary treatment, add solids in the secondary treatment, and reduce the solids to the digester.

"What Detergents Do to Sewage Treatment" is discussed by R. E. Anderson, W. E. Berg, and C. E. Johnson (120), who claim that detergents create a nuisance at a plant in which aeration is used, and apparently thrust a greater load on the secondary process. There are three types of detergents: Anionic, cationic, and neutral. Their advantage to the housewife is that they do not react with the dissolved solids in the water to form precipitates as do natural soaps. Anionic detergents are less expensive. Some synthetic detergents do not foam. The manufacturer may add a foaming agent to satisfy the housewife.

Atomic Weapons and Atomic Wastes.—The effects of atomic weapons are described in a 456-page book prepared under the direction of the Los Alamos Scientific Laboratory (121), in New Mexico, as a source of scientific information for technical personnel engaged in civil defense planning activities. Anyone planning civil defense against atomic attack may obtain a concept of large-scale planning in a 266-page book (122) entitled "Chicago Alerts," showing how a city plans its civil defense against atomic attacks. Doubtless, similar reports are available elsewhere for other localities.

Radioactive wastes (123) may be discharged into streams, rivers, and lakes in limited amounts. Methods for handling radioactive wastes include storage, evaporation, ion exchange, adsorption agents, chemical coagulation, biological methods, or combinations. Usually a residue results, which may be disposed of by: (*a*) Storage, which is convenient for handling short-life isotopes; (*b*) evaporation, which is sure but expensive; (*c*) ion exchange, which is promising for use in the laboratory; (*d*) chemical coagulation, which is usually obtained by the use of iron and lime, except if applied to mixed wastes, for which phosphates may be useful; (*e*) adsorption agents, which have limited use; and (*f*) biological methods, which are limited to a few installations.

Color Pollution.—Inasmuch as the public frequently assumes that pollution by color is the worst form of pollution, M. A. Churchhill, A.M. ASCE (124), has studied and written of the natural reduction of paper mill color in streams, citing a study of the Tennessee River in 1948 and 1949 to determine whether the high colors observed in the upper river were merely reduced by dilution with relatively clear local inflows or were reduced in color by natural processes.

These studies are concerned with distances of up to 150 miles. The principal sources of color were the black liquor from the digesters and the white water.

Trickling Filters.—Under conditions such as are found in Florida and other southern states, George R. Grantham, A.M. ASCE, Mr. Phelps, W. T. Calaway, and D. L. Emerson, Jr. (125) (126), conclude from experimental work at the Florida Experimental Station, at Gainesville, that it is economically advantageous to construct filters 4 ft deep instead of at the more common 6-ft depth.

Tentative Standards for Sewage Works.—"The Tentative Standards for Sewage Works," (127) prepared by the Committee on Uniform Sewage Works Standards of the Great Lakes and Upper Mississippi River Boards of Public Health Engineers, are now used by the Wisconsin State Board of Health as a guide for determining the adequacy of plans for sewers and sewage treatment works submitted for approval.

Disposal of Sewage and Sludge

Use of Reclaimed Sewage.—Under California conditions, with a shortage of water supply looming in certain regions, Mr. Rawn, Harold E. Hedger, M. ASCE and Carl E. Arnold, A.M. ASCE (128), investigated the application of water to be reclaimed to percolation beds for replenishing underground storage. In this manner, suitably treated sewage may be returned to the ground water and used over again. A field study was recently completed by R. Stone, A.M. ASCE, and Mr. Garber (129) at Whittier and Azusa, in California, in a larger basin underlain by coarse gravel soil.

Use of Sludge as Fertilizing Material.—From 1934 to 1939, Milwaukee, Houston, and Pasadena, Calif., were the only three sewage treatment works in the United States selling heat-dried activated sludge. In 1939, The Sanitary District of Chicago entered the field on the basis of sales in bulk carload lots, f.o.b. cars at the sewage treatment works in Chicago. In 1942, Pasadena abandoned sludge drying.

Since June, 1947, Milwaukee has sold its entire output in bags. The cost of marketing at Milwaukee has been steadily rising, because it includes the cost of storage, blending, bagging, and loading the bags in box cars, lined with heavy paper, for final shipment. Milwaukee guarantees 6% nitrogen content (7.29% ammonia), but in Chicago there is difficulty in reaching 5% nitrogen content (6.08% ammonia). In the sludge from both cities, the available phosphoric acid (APA) content is nearly the same. The granular structure of the Milwaukee sludge is somewhat coarser than that of the sludge of The Sanitary District of Chicago.

Houston currently is selling its sludge to an exclusive agent, in bulk, from $14.50 per ton to $17.00 per ton, according to the content of ammonia. At Chicago, the recent prices have been around $15.66 per ton for the product from the Southwest plant.

Sale of Heat-dried Activated Sludge.—On July 17, 1951, The Sanitary District of Chicago entered into a contract for a period of 2 years with H. J. Baker & Brothers, who agreed to purchase heat-dried activated sludge in bulk in carload lots, f.o.b. the sewage works, at a base price per ton of $2.50

per unit of 1% of ammonia plus $0.36 per unit of 1% of APA, said price to be as of June 4, 1951, and adjusted monthly on the last day of the calendar month, using the ratio of the price index as computed (based on current market prices published in the most recent issue of the *Oil, Paint and Drug Reporter* preceding the last day of each calendar month or on that date if that be the case) to the price index as of June 4, 1951, namely, 57.081. The base prices in the contract are multiplied by this ratio. From the quotations in the *Oil, Paint and Drug Reporter*, the price index is computed. The percentages of the items used in determining the price index are:

Items	Percentage
Ammonia, anhydrous fertilizer, in tanks, at works, per ton	60
Ammonia sulfate, coke-oven, in bulk, at producing ovens, per ton	30
Superphosphate, run of pile under 22% APA, pulverized, in bulk, at Baltimore, per ton	10

Recently, the City of Los Angeles advertised for bids on a 10-year contract for the sale of heat-dried digested activated sludge in bags averaging 3% of nitrogen (3.6% ammonia). The first bids received were rejected as being too low. A short-term contract was made at $7.00 per ton, but later, in June, 1951, a 10-year contract was awarded to the high bidder at $10.16 per ton of "pelletized" dried sludge, the contractor to furnish the bags and bag the material. Because there are no rail facilities at the Los Angeles plant, such material has to be trucked. The contract contains certain profit-sharing provisions in addition to the regular $10.16 price.

Sale of Dried Digested Sludge.—At San Diego, a relatively low-grade heat-dried digested sludge was sold under contract in 1951 for $7.00 per ton in 100-lb sacks, f.o.b. the plant, the contractor supplying the sacks. The sludge analysis was as follows: Nitrogen, 2.24%; P_2O_5, 3.99%; and K_2O, 0.33%.

The Los Angeles County Sanitatation Districts continue to sell air-dried digested sludge, delivered wet on the drying beds, to the Kellogg Supply Company at a net price of approximately $2.00 per dry ton.

Baltimore is now constructing a sludge-drying plant for the heat-drying of vacuum filter cake derived from digested primary, activated, and humus tank sludge, for the local market. Data compiled by William S. Foster, A.M. ASCE (130) on the sale of sewage sludge by a number of municipalities in the United States show that prices vary considerably and are generally much lower for ordinary digested sludge than for heat-dried activated sludge.

Air-dried digested sludge is usually given away, as at Baltimore, Chicago, Cleveland, Gary, Ind., and elsewhere. Commercially, this is not considered a fertilizer, but may prove a good soil conditioner.

Because of the loss of an outlet for its digested sludge cake, Washington, D. C., is installing sludge-drying and incinerating equipment to burn the sludge cake in the winter and sell it heat-dried in the summer, if a market can be developed. In the 1950 fiscal year, 28,612 tons of filter cake were produced (43) at the District of Columbia works, of which 38% were shipped to the District Department of Corrections at Lorton, Va. Fort Meade (Md.) and Fort Belvoir (Va.) received 7,978 tons, and the remaining 9,695 tons, or 34%

of the total production, was hauled away by trucks for use as topsoil dressing. The penal institution considers the sludge to be of very low fertilizing value.

Toledo reports (44) that in 1950 its sludge was sold in bags for a gross price of \$12.21 per ton and a net return of \$7.40 per ton after deducting the cost of bags and the cost of processing or manufacturing. The deduction has risen from \$2.99 per ton in 1942 to \$4.81 per ton in 1950. The 1950 sales were 1,083 tons of dry solids, part of which was material dried and pulverized in 1949. This is less than 20% of the digested sludge, the remainder being disposed of in a marsh lagoon.

The Agricultural Use of Sewage Sludge and Sludge Composts.—This subject has been investigated (131) by the Agricultural Research Council of Great Britain.

Compost.—Basically, composts are equivalent to air-dried or heat-dried digested sludge as a soil conditioner. The subject of composting is discussed in a manual of the Federation of Sewage Works Associations (132) and has occasioned comment among foreign engineers, particularly in Great Britain rather than in the United States, principally because of the doctrines of Sir Albert Howard (133). Recently, in Auckland, New Zealand, in connection with a study of the treatment and disposal of sewage in the Auckland Metropolitan Drainage District, the Auckland Drainage Commission (134) concluded that

> " *** the Drainage Board's proposals for the utilization of sewage by the production of an air-dried digested sludge which could be used either as an activator in the manufacture of compost or for conversion to a heat-dried pulverized fertilizer should be adopted."

The status of composting for disposal of organic refuse is presented (135) by the University of California, at Berkeley. Recently a promotional effort has been made to sell, on a commercial basis, a compost prepared from garbage.

The material as offered in the Chicago area contains about 40% moisture, and on a dry basis: Nitrogen, 1.79%; phosphoric acid total, 4.51%; and APA, 3.79%. The analysis of this material is similar to that of digested sewage sludge, with slightly higher P_2O_5 content. It is offered in bags at \$4.95 per 100 lb, or \$68.00 per ton, f.o.b. the plant. No claims are made as to nitrogen, phosphorus, or potassium content. "No chemicals are added to the finished product."

Synthetic Topsoil.—Owing to the scarcity of topsoil for park uses in New York City, the Department of Parks is undertaking a program (136) of utilizing digested activated sludge as a source of organic matter (from 40% to 60% of dry weight), nitrogen (from 1% to 3%), and phosphoric acid (from 1.5% to 3%). The sludge is barged in liquid form to the proposed site and is distributed either by contour lagooning, by gravity irrigation, by sprinklers, or by slotted pipe (protected by screens in the pipe). Air-drying also has been investigated. The soil is prepared first by disking to mix sand and clay, where clay has been applied to sand, and liquid sludge is then distributed to a depth of 18 in. in doses of from 1 in. to 2 in. at a time. The experimental work is completed. The Park Department is about to start the first large-scale operation in Marine

Park, Brooklyn, on an area filled with collected refuse and covered with 2 ft of sand. In the next 9 years nearly 900,000 cu yd of air-dried sludge will be used on 1,565 acres. The cost of preparing topsoil by this method is about $1,000 per acre as compared with $4,500 per acre for natural topsoil.

Possible By-Products from Activated Sludge.—A relatively new vitamin, B-12, has been isolated (137) (138) in activated sludge, in amounts of from 1.1 milligrams per lb to 4.2 milligrams per lb of dry solids. A vitamin content of 1.5 milligrams per lb has been proposed as a required level for commercial feed supplement for chickens. Chicken-feeding tests are being conducted by H. R. Bird, Bureau of Animal Industry, United States Department of Agriculture, at Beltsville, Md. Recently (139) at Milwaukee, a newspaper interview with J. F. Friedrich, the chairman of the commission, revealed that experimental work has been conducted by the Milwaukee Sewerage Commission for several years on the extraction of B-12 from its fertilizer, and that application has been made for a patent on the process. Furthermore, a patent has been obtained for the production of alcohol from an as yet unidentified element in its fertilizer.

The Battle Creek Sewage Plant heat dries under contract a waste product derived from the manufacture of penicillin by the Upjohn Company at its antibiotics plant. This material, known as penicillin mycelium, is sold to feed producers for addition to regular hogfeed, chickenfeed, and horse fodder, and it is adaptable to the diets of dogs and fish. The sludge gas from the sewage works is used for drying, and the handling and stockpiling of sludge cake from the drying beds is paid for by the contractor (140).

Dual Disposal of Garbage with Sewage.—The description of the dual disposal of garbage and sewage presented in the last report of this Committee (7) may be supplemented by a recent procedure.

In Indiana, the City of Jasper (5,213 population in 1950) is reported (141) to have installed 830 garbage grinders by March 1, 1951, satisfactorily servicing 70% of the families in Jasper and its neighborhood (142) (143). An increase of 15% to 20% is indicated in the amount of grease reaching the treatment plant. In planning the project (144), Lawrence I. Couch, M. ASCE, and Harvey J. Kulin estimated an increase in sewage flow at 2 gal per capita per day (about 2% by 1970). For the B.O.D. loading from the garbage, an additional load of 0.05 lb per capita per day was assumed. The digester capacity was increased to 6.5 cu ft per capita, or about 55%; the capacity of the sludge-drying beds was increased 60%; and the capacity of the aeration tanks was increased 50% (144).

The low bidder for construction of the sewage treatment plant estimated the cost at $301,000, of which $46,000 was accounted for by the provision for the garbage. The grinders were installed at a price of $74.17 per home, paid by the householders.

To determine the effect that garbage grinders have on the sewage flow, Mr. Rawn (145) made a test in the Sanitation Districts of Los Angeles County, on an area comprising 1,220 homes on 204 acres (with a population of 4,000), each house being equipped with a grinder. The average flow for a period of 3 weeks was 48.7 gal per capita per day. The average analysis for 2 days for a

flow of 48.7 gal per capita per day was:

Constituent	Ppm	Lb per capita per day
Suspended solids	380	0.154
Total solids	1,690	
Grease	115	0.047
Five-day B.O.D.	390	0.158

The estimated increase in loading caused by ground garbage was:

Constituent	Lb per capita per day	Percentage
Suspended solids	0.047	44
B.O.D. total	0.054	52
B.O.D. filtrate	0.023	66
Grease	0.028	147

From an investigation at Detroit, C. L. Palmer, M. ASCE, and Mr. Nusbaum (146) have concluded that 25% of the dry solids in garbage goes into solution or nonsettling suspended matter; and that, when ground, not more than 30% on a dry basis should pass a No. 40 sieve.

In a symposium on household food waste disposers, Robert L. Anderson (147) has noted that universal adoption of grinders would be necessary if the methods of collection and disposal were to be measurably affected, and has stated that

> "*** it is unthinkable that universal installations can be obtained at a cost of $170.00 for each family, where it is not now possible even to get householders to provide garbage cans, as in Chicago."

In many cases, garbage composes less than 10% of the total volume of refuse collected. By far the larger proportion of municipal refuse cost is in collection, and the removal of 10% of the material to be collected will result in little saving.

E. J. Zimmer (147) has studied the effects that the use of food wastes disposers have on household plumbing installations, and has concluded that, if 2.5 gal of water per min are used, at a temperature of less than 110° F, no trouble results. A. L. Tholin, M. ASCE (135), has discussed the effect of household food waste disposers on sewer systems and has concluded that with a velocity ranging from 1 ft per sec to 2 ft per sec, no trouble should result. N. E. Anderson, M. ASCE (147), has reviewed the effect of household garbage grinders on sewage treatment works and has concluded that the grit content may be increased as well as the quantity of solids removed as sludge, but that gas production in digestion tanks may be increased 30%. He considers a household grinder to be a luxury and not justified on the basis of economy.

Mr. Haseltine (148) considers that the designers and operators of sewage works need not be concerned about the use of garbage grinders in more than half of the homes. Assuming a per capita green garbage production of 0.6 lb per day containing 75% moisture, Mr. Haseltine has estimated that, if all the garbage in a community was ground and added to the sewage, the suspended matter and B.O.D. of the raw sewage would be increased by 50%. He con-

cludes that finely ground garbage will not affect the municipal sewers or house plumbing. However, he has warned that garbage grinding may increase the grit from 23% to 80% with central grinding and, to a lesser degree, with domestic grinders. He has estimated that the addition of all the ground garbage to the sewers may increase the content of suspended solids in the effluent of the primary settling tank by from 5% to 10%, and of the B.O.D. by from 15% to 30%. The sludge volume may be increased by 100%, and its volatile content by from 150% to 175%.

Ground garbage has been successfully digested when mixed with sewage sludge in ratios varying from 0.3 parts to 1.5 parts of dry volatile garbage solids per part of dry volatile sewage sludge solids. At least 16 cu ft of gas may be expected per pound of volatile garbage solids digested, which compares with 15 cu ft per lb to 18 cu ft per lb of volatile sewage solids digested. However, H. E. Babbitt, M. ASCE, reports little or no success in digesting garbage mixtures in Imhoff tanks in winter.

F. E. Schoonover, Jr., reports (149) that Herrin, Ill. (having a 1950 population of 9,401), has adopted household garbage grinding and is buying grinders in lots of one hundred.

New York City regulations do not permit the introduction of ground garbage into the municipal sewers.

Upon the completion of its new Northeast sewage treatment works, Philadelphia (150) has lifted the ban on kitchen garbage grinders in the sections of the city serviced by that plant. Prior thereto the dumping of deleterious matter into the sewers was banned by an ordinance enacted in the late 1860's.

The Michigan legislature is reported to have passed a bill permitting the City of Detroit to purchase disposal units and rent them to householders. Financing would be done from regular revenues or credit bonds. As yet it has not decided whether the rental fee would be included in the water bills. The City of Dearborn, Mich., requires grinders in all multiple-family dwellings of more than four units, and in all commercial establishments.

The use of garbage grinders is still in a promotional stage. Eventually, the propaganda may diminish and reason and economics prevail. Meanwhile in the large communities, like that of The Sanitary District of Chicago, the outcome is being watched with interest and with little apprehension for the future.

Marion, Ind.—The municipal garbage at Marion (151) is ground at a single grinding station at the plant site. In 1950, 274.4 tons per day of solids originated from garbage and 1,895 tons from sewage. The sale of 23,591 loads (152) of liquid sewage sludge to 46 farmers within a 6-mile radius during 1950 produced $2,454.55. The sewage works collected and handled 1,752 tons of green garbage.

Sewer Service Charges.—The Joint Report of Committees of the ASCE and the Section of Municipal Law of the American Bar Association and others (153) has appeared. This report covers fundamental considerations as to rates and rate structures for water and sewage works, with chapters about the elements and functions of water and sewage works, as well as publicly-owned and privately-owned utilities, about the financing of privately-owned utilities, about

the determination of annual revenue requirements, about present practices in obtaining total annual revenue for water and sewage works, about recommended procedures for establishing fair rates and rate structures, and about methods of enforcing payment of water and sewage charges.

This joint group concludes that the fundamental principle regarding rates and rate structures should be:

> "The needed total revenue of a water or sewage works shall be contributed by users and non-users (or by users and properties) for whose use, need, and benefit the facilities of the works are provided approximately in proportion to the cost of providing the use and the benefits of the works."

The joint group finds that—

> "*** no common practice in either water or sewage works; that present rates have been fairly determined to comply with the fundamental principle."

> "Existing enabling legislation varies widely. In most states further legislation would be necessary to enable water and sewage utilities to give full effect to the principle put forward by this report."

Samuel A. Greeley, Hon. M. ASCE, has explained methods of building and financing sewage works, in general (154).

Various problems of rate making have been explained by E. E. Bankson, M. ASCE (155) (156), for the Allegheny County Sanitary Authority and A. R. Vollmer, M. ASCE (157), has outlined suggested sewer-service charges for the sewerage project at Wilmington.

At Buffalo, within the Sanitary Authority area (158), owners of real estate bear approximately 45% of the sewer rental burden, and users of water bear 55% of the burden, the combined revenues producing the major part of the annual budget requirement for the payment of bond principal and interest, for reserves, for operation, for maintenance, and for the repair of the sewerage and disposal system. There is a special charge for handling industrial wastes of unduly high concentrations. Four outside communities have agreements with the authority. At Bath, N. Y. (158), a village of 5,000 population, the bond service is a part of the tax item in the village budget. Operating expenses are met by a charge based on the water use.

In New York City (159), an ordinance for sewer rental was adopted on July 1, 1950. Rents equal to one third of the water charges were made to each property. The yield expected was $15,000,000. Actually, under the stress of water conservation, the yield has been approximately $14,000,000.

On the Blackstone Valley project (160) while the district builds its treatment plant, unfinished sewers earn an income (although construction is only 20% completed), averaging around $7,500 per month from a service charge of $64.50 per million gal levied against five municipalities and eight industries discharging into 3.5 miles of completed sewer. As the project progresses, the nature of the wastes is ascertained (75% of the flow is from industrial wastes, chiefly textiles). Each industry is required to install a flow meter. Temporary chlorination of intercepted wastes (about 5 mgd) uses approximately 3,550 lb of chlorine per day.

Charges for Handling Industrial Wastes in Municipal Plants.—This topic was reviewed in the last Committee report (7). The information now available indicates that in the United States at least 18 municipalities have a special charge for the disposal of liquid industrial wastes. The charge proposed in 1950 by The Sanitary District of Chicago under a special statute has been shelved, without any definite action.

Bathing Beaches.—In a review of suggested standards for natural waters used for bathing, C. R. Cox, A.M. ASCE, summarizes (161) existing practice and indicates that further effort is needed to clarify the situation and to develop "*** more precise analytical methods to disclose the bacterial quality of bathing waters in a more definite manner than is now possible."

John S. Delos (162) describes a bacteriological survey of streams and bathing beaches at Cleveland, indicating that, in 1949, the beaches were grossly polluted, particularly in rainy weather.

The Water Resources Commission of the State of Michigan (81) comments on the prevalence and control of "swimmers itch." Swimmers itch is a type of dermatitis produced by the penetration of certain larvae flukes (schistosome cercariae) into the human skin in water. The hosts are snails which become infected. The disease is scattered over the United States, but is most prevalent in the lake regions of the North Central States, including Minnesota, Wisconsin, and the adjoining Canadian province of Manitoba, all of which furnish a favorable habitat for the snail hosts, and are popular for bathing. In Michigan, a cooperative program has been adopted for examination of the lake bottoms and shores, followed by a treatment with an 8-in. layer of concentrated copper sulfate-hydrated lime solution introduced subaqueously over the beach floor. The state pays 60% and the benefitted frontage pays 40% of the cost of the operation.

Problems of Nitrogen and Phosphorus in Sewage Disposal.—The effect of sewage effluents on aquatic plants creates a problem that remains to be soived.

W. W. Eckenfelder, Jr., and J. W. Hood (163) have considered the vital role of ammonia nitrogen in biological treatment, both in trickling filters and activated sludge and in sludge digestion, and have concluded that the role of unoxidized nitrogen as ammonia in receiving streams is not clearly understood.

> "Apparently fertilization in a greater or lesser degree, immediate or deferred, occurs with the deposition of unoxidized forms of nitrogen and is inevitable. Of paramount importance, however, is the cxygen demand loading imposed upon streams by the deposition of unoxidized nitrogen in ammoniacal or organic form. Based upon D.O. standards for fish propagation, the B.O.D. due to nitrification may be as important as the so-called carbonaceous demand."

H. O. Lord, M. ASCE, has reviewed (164) the history of the disposal of sewage and sewage effluent at Madison, Wis., and has outlined possible ultimate requirements in providing satisfactory sewage treatment. Because of the effect of nitrogen and phosphorus in fertilizing weeds and algae growths, a practical means is sought for removing nutrient materials from sewage plant effluents.

W. L. Lea and G. A. Rohlich, A.M. ASCE (165), in a pilot plant at Madison have reduced the phosphorus content of sewage works effluent from 7.0 ppm to 0.7 ppm. About 60% of the organic nitrogen is removed and 84% of the B.O.D. The process utilizes flocculation, involving the addition of approximately 200 ppm of alum, and mixing for 15 min, then settling to remove alum and phosphorus as sludge. Recovery of the alum and phosphorus is effected by treatment of the sludge with sodium hydroxide to bring both into solution. Calcium chloride is added and calcium phosphate settles out. The sodium aluminate is reused and recovers about 93% of the alum. Cost data are lacking.

Eradication of Weeds.—In 1946, luxuriant growths of wild hemp (marijuana) were found on wild lands of The Sanitary District of Chicago. Mechanical and chemical means of brush and weed control and 2, 4- Dichlorophenoxyacetic Acid (2, 4-D) sprays proved helpful (166). Flame throwers were also tried. Later, a mixture of 2, 4-D and 2, 4, 5-Trichlorophenoxyacetic Acid was found to be more effective. Where clear surfaces were required, 90% of sodium Trichloroacetate (TCA DuPont) was also applied. The most effective chemical brush killer was found to be ammonium sulfamate (also known as "Ammate") weed killer. At the Minneapolis-St. Paul sewage treatment works, the yearly cutting of brush proved expensive. In 1949, 2, 4-D sprays were tried. Later, "Ammate" again proved effective.

Great Lakes Levels.—In 1929, to preserve and improve Niagra Falls, a convention was entered into by Canada and the United States, modifying the diversion for power at Niagra Falls as fixed by the Boundary Waters Treaty of January 11, 1909. This was amended in 1940, to permit the Province of Ontario to divert water from the Albany River Basin to Lake Superior and to withdraw an additional 5,000 cu ft per sec at Niagara Falls for power purposes.

From 1945 to 1950, the combined diversion has ranged from 4,202 cu ft per sec to 6,224 cu ft per sec. Because of high water levels in Lake Superior, the diversion was discontinued on May 4, 1951.

Litigation

Pollution of the Androscoggin River.—The pollution problem on the Androscoggin River in Maine was reviewed in the report of the Committee (7). Walter A. Lawrance, the administrator appointed by the Court, has reported (167) that pollution control to the extent of preventing aerial nuisance has been accomplished in three ways: By regulation of the amount of sulfite pulp produced; by storage of concentrated digester liquors, in lagoons during the critical summer season at two of the three pulp and paper company plants; and by the application of sodium nitrate to the river. A total of 641.5 tons of sodium nitrate were added to the river during 44 days in the summer of 1949. Nitrate was again added in the summers of 1950 and 1951. When added to the water that was about to become anaerobic, the nitrate oxygen was readily utilized and ammonia was the principal reduction product. The addition of sodium nitrate permitted a more flexible and economic use of the river as a carrier of sulfite waste liquor by reducing the capacity to create a hydrogen sulfide odor nuisance. The nitrate program cost $45,000, exclusive of capital expenditures.

How the British Engineers View United States Practice

M. R. V. Daviss has commented (168) on sewage treatment practice in the United States as observed on a trip lasting from September 19, 1950, to October 31, 1950. He has declined to state that the Americans are more advanced than the British, but concludes that

> "*** there is far more academic research being done in America than in Britain and I think that the Americans accept plants which require more mechanical maintenance than we would or could tolerate."

He was impressed with the complete enclosure of the preaeration and settling tanks at the Hyperion plant, and with the complete enclosure of the aeration and sedimentation tanks at the San Francisco Southeast plant, and at the New York Owls Head plant. In sludge treatment, he noted a great difference between American and British practice for large works, particularly in the use of vacuum filters in the United States—because in England there are only two such installations.

J. B. Rowntree (169) observed sewage treatment practice, from July to November, 1949, chiefly in the United States and Great Britain and was impressed by the combination of appearance and utility in the United States, and by the facilities provided for the operating staff. He found the average American plant more modern in appearance and design, influenced by the national tendency towards mechanization. A striking difference between Great Britain and the United States exists in the strength and volume of the sewage, and the widespread use of chlorine in the United States.

Viability of Organisms in Soil, Water, Sewage, and Sludges, and on Vegetation

In a comprehensive review on the occurrence and survival of enteric, pathogenic, and relative organisms in soil, water, sewage, and sludges, and on vegetation, Mr. Rudolfs, L. L. Falk, and R. A. Ragotzskie have discussed the viability of bacterial and virus diseases (170) and animal parasites, such as Endamoeba, Histolytica, and Helminth (170*b*). They have summarized present-day knowledge (170*d*) and offer the following general conclusions:

> (1) "No evidence was found that pollutional bacteria, amoeba, or helminth eggs penetrate healthy, unbroken surfaces of vegetables or cause internal contamination."
>
> (2) " *** vegetables to be eaten raw can be grown without health hazard in soils that have been subject to sewage irrigation, night soil application, or polluted stream water irrigation in years prior to the season in which the vegetables are grown."
>
> " *** The only reliably effective method for decontamination of bacterial, amoebic, and helminthic organisms is pasteurization at 60 deg C. for 5 min."

Sewage Treatment in Low-Temperature Areas

The problems of sewage treatment in low-temperature areas are reviewed in detail by H. A. Thomas, Jr., M. ASCE (171), with suggestions as to design and the need for additional data.

Respectfully submitted,

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Committee on Sewerage and Sewage Treatment

October 23, 1951

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